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Modeling and Characterization of Recompressed Damaged Materials

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Figure Caption:

Spall damage in copper specimen before and after 15% compression. Significant compression has occurred outside of the damaged region.

Annual Report Text:

Ductile metals subjected to shock loading can develop internal damage through nucleation growth and coalescence of voids. The extent of damage can range from a well-defined spall plane induced by light shocks to more widespread damage caused by strong shocks. Because damage materials are often part of a dynamic system, significant additional deformation can occur in extensively damaged materials. To represent material behavior in simulation codes for stockpile stewardship calculations, both the damage and the recompression processes must be modeled accurately. Currently, no experimentally based models of recompression behavior are available for use in numerical simulations.

The goals of this project are to (1) perform recompression experiments on samples containing controlled and well-characterized damage, (2) develop a model capturing the recompression behavior and residual strength based on the experimental data and micro-mechanical models, and (3) implement the model in an Advanced Simulation and Computing (ASCI) code (ALE3D). The recompression model, together with failure models based on underlying physical mechanisms, will provide a more accurate representation of material behavior-information that is needed for simulations of explosively loaded materials such as those required by the Stockpile Stewardship Program.

The experiments involve creating a controlled level of damage internal to specimens in the form of spall-induced porosity. The material is then compressed to close the porosity and subsequently tested to determine the strength of the recompressed material. Samples are taken from each stage of the process to observe the damage level through standard metallographic techniques. For the experiments conducted in FY01 and FY02, the spall damage was introduced in the copper specimens through impact experiments conducted on a light gas gun. The damaged material was recovered and compressed 15% at quasi-static strain rates and in a split Hopkinson bar at dynamic strain rates of 3000 per second. Following recompression, tensile specimens were machined and tested to assess the residual strength of the material.

The strength of the damaged region during compression was unexpectedly high. Although the spall related porosity accounted for a significant fraction of the total area on the spall plane, the strength of the damaged region in compression was high enough to resist deformation while the surrounding material deformed. A large fraction of the 15% compressive deformation occurred outside of the damaged region. It is believed that this is due to be the significant strain hardening of the highly strained material surrounding the voids.

Additional experimental and simulation work is planned for FY03 to better define and characterize the material response during recompression. Simulations will be used to determine the role of strain hardening on the void closure behavior. Recompression experiments will be pursued using higher pressures available with a gas gun and lasers. The laser experiments are particularly interesting since they access a much higher pressure and strain rate regime. The additional data will give more confidence in the model when applied under extreme conditions.

Does your current text contain possible patentable material? No

Publications

No publications.